Thirty-Day Readmission Rate and Costs After Percutaneous Coronary Intervention in the United States

A National Readmission Database Analysis

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Background—The association of short-term readmissions after percutaneous coronary intervention (PCI) on healthcare costs has not been well studied.

Methods and Results—The Healthcare Cost and Utilization Project National Readmission Database encompassing 722 US hospitals was used to identify index PCI cases in patients ≥18 years old. Hierarchical regression analyses were used to examine the factors associated with risk of 30-day readmission and higher cumulative costs. We evaluated 206 869 hospitalized patients who survived to discharge after PCI from January through November 2013 and analyzed readmissions over 30 days after discharge. A total of 24 889 patients (12%) were readmitted within 30 days, with rates ranging from 6% to 17% across hospitals. Among the readmitted patients, 13% had PCI, 2% had coronary artery bypass surgery, and 3% died during the readmission. The most common reasons for readmission included nonspecific chest pain/angina (24%) and heart failure (11%). Mean cumulative costs were higher for those with readmissions ($39 634 versus $22 058; $P<0.001$). The multivariable analyses showed that readmission increased the $\log_{10}$ cumulative costs by 45% (β: 0.445; $P<0.001$). There was no significant difference in cumulative costs by the type of insurance.

Conclusions—In a national sample of inpatient PCI cases, 30-day readmissions were associated with a significant increase in cumulative costs. The majority of readmissions were because of low-risk chest pain that did not require any intervention. Ongoing effort is warranted to recognize and mitigate potentially preventable post-PCI readmissions. **(*Circ Cardiovasc Interv*. 2017;10:e005925. DOI: 10.1161/CIRCINTERVENTIONS.117.005925.)**

Key Words: chest pain ■ coronary artery bypass ■ heart failure ■ inpatients ■ percutaneous coronary intervention

The Centers for Medicare and Medicaid Services have used 30-day all-cause readmission rates for heart failure, acute myocardial infarction (AMI), and pneumonia as quality measures of hospital performance and have penalized those with higher rates of readmissions.[1–3] Recently, the spectrum of conditions evaluated for 30-day readmissions has been significantly expanded. In 2012, the hospital-wide readmission measure was introduced which also incorporates readmissions after cardiovascular procedures such as percutaneous coronary interventions (PCI).[1] In 2013, Medicare started reporting unplanned post-PCI readmissions on the Hospital Compare website.[4] Given the large volume of PCI performed annually, there is a growing interest in examining costs and factors associated with post-PCI readmissions.[5–12]

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There is significant variability in rates of post-PCI 30-day readmissions ranging from 15% to 19% in the Medicare population and relatively lower rates of 8% to 12% in other selected populations.[6–9,11,13] Studies have also suggested that nearly half of the short-term readmissions may be potentially preventable, and, therefore, this area remains an exciting avenue for healthcare cost reduction.[14] Although previous studies have examined short-term readmission in selected populations, the association of readmissions on overall costs has not been well studied.[6,9,12,15]

The objectives of this study were to evaluate the rate of post-PCI 30-day readmission and the associated costs in

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WHAT IS KNOWN

- The rate of 30-day readmissions after percutaneous coronary intervention ranges from 8% to 19% in select populations in the United States.
- Older age, female sex, and higher comorbidity burden are associated with increased risk of short-term readmissions after percutaneous coronary intervention.

WHAT THE STUDY ADDS

- In a national sample of hospitals, the mean rate of 30-day readmissions after inpatient percutaneous coronary intervention was 12%, and the majority of readmissions were for chest pain/angina, which did not require further interventions.
- Age, sex, and comorbidity index–adjusted risk of 30-day readmission were higher for Medicare compared with private insurance, larger metropolitan compared with smaller rural hospitals, and nonteaching compared with teaching hospitals.
- After adjusting for demographic, clinical, and hospital characteristics, the patients with 30-day readmission incurred 3% higher costs for index hospitalization and 45% higher cumulative 30-day costs.

a cohort of patients who had inpatient PCI. In addition, we examined the factors associated with the risk of 30-day readmissions and higher costs after accounting for all insurance types, geographical variations, and individual- and hospital-level factors.

Methods

Data Source

We examined the Healthcare Cost and Utilization Project (HCUP) National Readmission Database (NRD), which includes an estimated 36 million discharges in 2013 for all payer sources and the uninsured from >2000 hospitals across 21 states. All admissions pertaining to an individual are linked by a validated unique ID which can be used to track readmissions across different hospitals and state lines. Overall, NRD represents ≈50% of total hospitalizations in the United States and is therefore the largest national database to examine readmission patterns. These data include information on demographics, clinical characteristics of primary and secondary diagnosis/procedure codes, length of stay, discharge disposition, death, admission charge with validated costs to charge ratio, and hospital-level variables. In addition, data include sampling strata and admission weights, which allow computation of national estimates of rate and costs. *International Classification of Diseases*, Ninth Revision, Clinical Modification (ICD-9-CM) codes associated with primary and secondary diagnoses and procedures were used to ascertain clinical variables. This study was deemed exempt by University of Louisville Hospital Institutional Review Board as the NRD is a publicly available database that contains deidentified patient information. The data, analytic methods, and study materials are available to other researchers through the HCUP website, https://www.hcup-us.ahrq.gov, and may be used for reproducing the results.

Study Cohort

The study cohort included inpatient cases who were discharged alive after index PCI. We included patients ≥18 years from January through December 2013. The NRD only includes hospitalized PCI cases, and thus, elective outpatient PCI cases were not included in our study cohort. Consistent with the published literature, the following ICD-9-CM codes were used to identify PCI cases: 00.66, 75.55, 36.01, 36.02, 36.05, and 36.06. We included the first admission as the index case for patients who had >1 PCI within 30-day period, and a subsequent admission was counted as a readmission. We excluded those who died during the index hospitalization and were discharged after November 30 and those who had missing data on length of hospital stay. The time period from January through November allowed complete 30-day follow-up on all participants up to December 2013.

Variable Ascertainment

ICD-9-CM codes were used to define clinical variables: AMI at index admission and other pertinent comorbid conditions including ischemic heart disease, heart failure, peripheral artery disease, chronic pulmonary disease, diabetes mellitus, and renal failure. All primary and ≤14 secondary diagnoses associated with the admission were used to define comorbid conditions. We also calculated an index for severity of comorbid conditions using the Deyo modification of Charlson Comorbidity Index. This index contains 17 comorbid conditions with differential weights, and the score ranges from 0 to 33 with greater score corresponding to greater burden of comorbid disease. Details of codes used for defining each condition and Charlson Comorbidity Index are presented in Tables I and II in the Data Supplement. Other covariates included demographics, median household income by zip code of residence, payor source/insurance, pertinent hospital factors such as size, location, teaching status, and variables pertaining to hospitalization, such as length of stay, and elective status. Of note, a hospital was regarded as a teaching facility if it is affiliated with an American Medical Association–approved residency program or is a member of the Council of teaching hospitals, or had a full-time equivalent resident to patient ratio of ≥0.25. Table 1 provides details of all covariates included in the study.

Outcome Variables

The primary outcome variables included 30-day readmission and readmission costs. Thirty-day readmission was defined as any inpatient admission (all cause) within 30 days of discharge from index PCI regardless of whether elective or nonelective PCI was performed. Transfers to other hospitals or rehabilitation facilities after index PCI were not considered as readmission. Only the first readmission within the 30 days was included in the analysis. Time to readmission within 30 days was calculated as per HCUP recommendations, that is, from discharge date after index PCI to readmission date.[16] The data include total charge by the hospital for each admission. To calculate the estimated costs of hospitalization, data were merged with costs:charge ratio available for each hospital from HCUP. The total costs for hospitalization were calculated by multiplying total charges with the appropriate costs:charge ratio. This methodology has been previously validated and has been used extensively in the literature.[16,17] Reasons for readmission were ascertained using primary diagnosis categories and the corresponding HCUP Clinical Classification Software. Details of ICD-9 codes associated with primary diagnosis and the corresponding Clinical Classification Software are presented in Table II in the Data Supplement. Secondary outcomes included inpatient mortality during the 30-day readmission. Of note, we did not have information on patients who had out-of-hospital mortality.

Statistical Analyses

HCUP NRD was sampled to represent a large universe and provides discharge sample weights, which are calculated as the ratio of total discharges to the discharges in the sample for each stratum. The sample weights could be used for computing national estimates using validated methodology.[16] We calculated national estimates of 30-day readmission rates and the associated costs after accounting for sampling strata and within hospital clustering—SAS procedure, SURVEYMEANS, was used for the analyses. A preliminary descriptive analysis was done to study data distribution and to examine the

Table 1. Individual- and Hospital-Level Factors Associated With Readmission Within 30 Days of Percutaneous Coronary Intervention

Variable	Overall (n=206 869)	30-Day Readmission (n=24 889;12%)	No 30-Day Readmission (n=181 980; 88%)	*P* Value	Final Model aOR (95% CI)*
Age, y	65.0±12.4	67.2±12.7	64.6±12.1	<0.001	1.01 (1.00–1.01)
Age group					n/a
18–64 y	48.1%	40.5%	49.1%	<0.001	
≥65 y	51.9%	59.5%	50.9%		
Female	32.2%	38.7%	31.3%	<0.001	1.20 (1.16–1.23)
Acute MI at index admission	58.1%	58.4%	58.1%	0.257	ns
Charlson Comorbidity Index†	1.8±1.2	2.3±1.3	1.7±1.2	<0.001	1.11 (1.08–1.13)
Comorbid condition					
Ischemic heart disease	66.5%	66.4%	66.5%	0.885	ns
Heart failure	21.4%	34.6%	19.6%	<0.001	1.37 (1.32–1.42)
Peripheral artery disease	10.6%	14.8%	10.1%	<0.001	1.09 (1.04–1.14)
Chronic pulmonary disease	18.4%	26.1%	17.4%	<0.001	1.20 (1.16–1.25)
Diabetes mellitus					1.05 (1.02–1.09)
Renal failure	14.4%	24.7%	13.0%	<0.001	1.41 (1.36–1.47
Percentile median household income by Zip					ns
0–25th	27.8%	30.7%	27.4%	<0.001	
26–50th	26.7%	26.6%	26.8%		
51–75th	24.5%	23.5%	24.6%		
76–100th	21.0%	19.1%	21.3%		
Insurance					
Medicare	54.0%	65.4%	52.4%	<0.001	2.57 (2.06–3.20)
Medicaid	7.0%	8.6%	6.8%		3.68 (2.68–5.07)
Other/self-pay/uninsured	6.8%	4.5%	7.1%		1.54 (0.99–2.40)
Private insurance	32.2%	21.5%	33.7%		1.00
Hospital bed size					
Large	72.7%	73.8%	72.6%	<0.001	1.09 (1.00–1.20)
Medium	21.4%	21.1%	21.5%		1.10 (1.01–1.20)
Small	5.9%	5.0%	6.0%		1.00
Hospital location					
Large urban metropolitan	54.0%	56.9%	53.6%	<0.001	1.11 (1.06–1.15)
Small metropolitan/rural	46.0%	43.1%	46.4%		1.00
Hospital teaching status					
Nonteaching hospital	46.5%	47.3%	46.4%	0.007	1.06 (1.02–1.11)
Teaching hospital	53.5%	52.7%	53.6%		1.00
Length of index hospitalization, d		5.5±6.8	3.5±4.9	<0.001	1.03 (1.029–1.03)
Admission type					
Nonelective	84.6%	87.3%	84.3%	<0.001	1.20 (1.15–1.25)
Elective	15.4%	12.7%	15.7%		1.00
Admission day					ns
Weekend	21.2%	22%	21.1%	0.001	
Weekday	78.8%	78.0%	78.9%		

Model also adjusted for interaction term between age and payor type. aOR indicates adjusted odds ratio; CI, confidence interval; MI, myocardial infarction; n/a, not applicable to the hierarchical logistic regression analysis model; and ns, not significant (not included in the final regression model).

*Represents final parsimonious hierarchical logistic regression model.

†Charlson Comorbidity Index is a composite score created from 17 comorbidities; higher scores have been correlated with greater morbidity and mortality.

univariate association of the covariates with the outcome variables using χ^2 test for categorical variables and Mann–Whitney test for continuous variables. Hierarchical or multilevel models, which take into account the effect of nesting (ie, patient-level effects nested within hospital-level effects in our study), were used for multivariable analyses. In these models, unique hospital identification number is incorporated as random effect creating a 2-level model. This methodology has been recommended by HCUP and has been widely used in previous studies.[10,16] Multivariable mixed effects logistic regression models were used to examine risk of 30-day readmission, whereas linear regression models were used for costs. For multivariable analyses, costs were log transformed to achieve a normal distribution. All multivariable models included the pertinent covariates as listed in Tables 1 and 2. Each multivariable model included interaction terms between age and sex and age and payor source. Statistically significant interactions were retained in the model along with their parent variables regardless of whether the parent variables were statistically significant or not. We created final parsimonious models by backward elimination, that is, sequential removal of variables with *P* value >0.05 and ensuring that removal of variables did not result in >10% change in the measure of association for the primary predictor variable (eg, readmission status was considered to be a primary covariate in the cost model). All statistical analyses were conducted in Statistical Analysis Software Inc, version 9.4 using 2-sided tests and a significance level of 0.05.

Results

Population Characteristics and Descriptive Results

The NRD included 229 429 PCI cases performed from January through December 2013 among hospitalized patients 18 years of age and older (weighted estimate=518 050). We excluded those who died during the index hospitalization (2.3%) and were discharged after November 30 (7.7%) or had missing data on length of stay (<1%). The final study sample included 206 869 (weighted estimate=467 488) patients who were discharged alive after index PCI from January through November 2013. The length of stay after index PCI was 0 day for 1% (same day discharge); 1 day for 23%; 2 days for 27%; 3 days for 18%; and ≥4 days for the rest 31% (Table 1).

The mean age of patients in the study sample was 65 years (SD, 12.4 years); and 32% were female. A majority of patients were served by Medicare (54%) followed by private insurance (32%), Medicaid (7%), and other/uninsured (7%). After index PCI, 12% (n=24 889; and weighted estimate=56 154) had 30-day readmission. Among those with 30-day readmissions, 3681 (15%) had coronary revascularization during readmission (3137 [13%] had PCI and 544 [2%] had coronary artery bypass surgery), and 841 (3%) died during the rehospitalization. The median time for readmission was 10 days (interquartile range, 4–19 days). The rate of 30-day readmission varied from 6% to 17% by hospital deciles of readmission (*P*<0.001; Figure 1).

Figure 2 presents relative frequency of primary diagnoses associated with 30-day readmissions. Among those with readmissions, the most common primary diagnoses codes included angina or nonspecific chest pain (24%), heart failure (11%), AMI (7%), procedural complications (7%), septicemia or pneumonia (6%), cardiac arrhythmia (5%), and hemorrhagic anemia or gastrointestinal bleeding (4%).

The mean hospital charge and payment/reimbursements (costs) of index PCI admission were $89 907 (SE=$1530) and $23 350 (SE=$325), respectively. For 30-day readmissions, mean charge and costs were $50 846 (SE=$836) and $13 055 (SE=$188), respectively. The cost of index hospitalization was $26 458 (SE=$365) for those with 30-day readmission compared with $22 058 (SE=$314) for those with no readmission (*P*<0.001). Cumulative 30-day costs (index PCI+30-day readmission, if any) for those with readmission were $39 634 (SE=$497) compared with $22 058 (SE=$314) for those with no readmission (*P*<0.001). Median length of stay for readmission was 3 days (interquartile range, 2–5 days).

Predictors of 30-Day Readmission and Costs

Table 1 presents the results of multivariable hierarchical logistic regression analysis for the predictors of 30-day readmission. The results showed that female sex, higher Charlson Comorbidity Index, and chronic comorbid conditions including heart failure, peripheral artery disease, chronic pulmonary

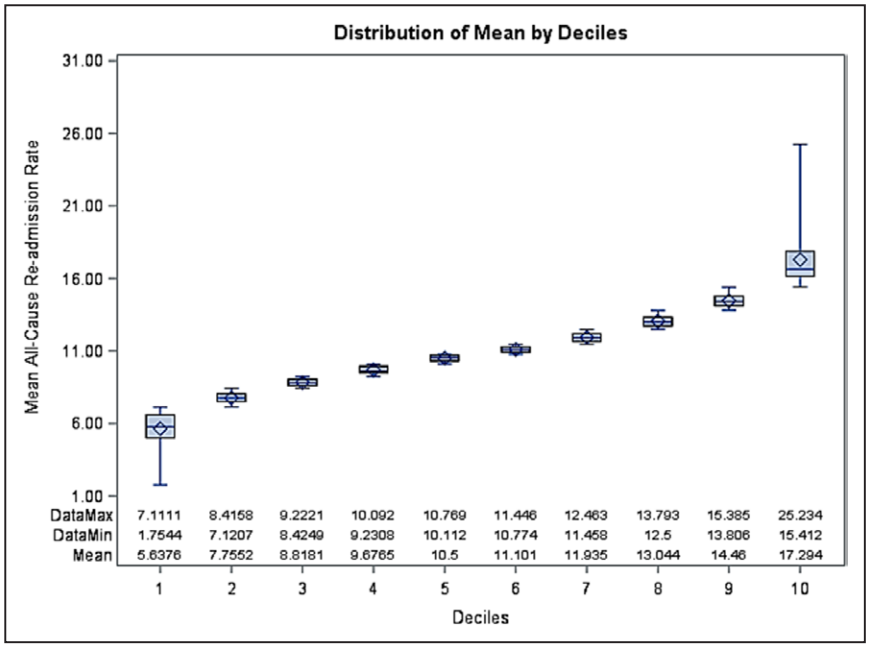

Figure 1. Hospital deciles of 30-day readmission after percutaneous coronary interventions.

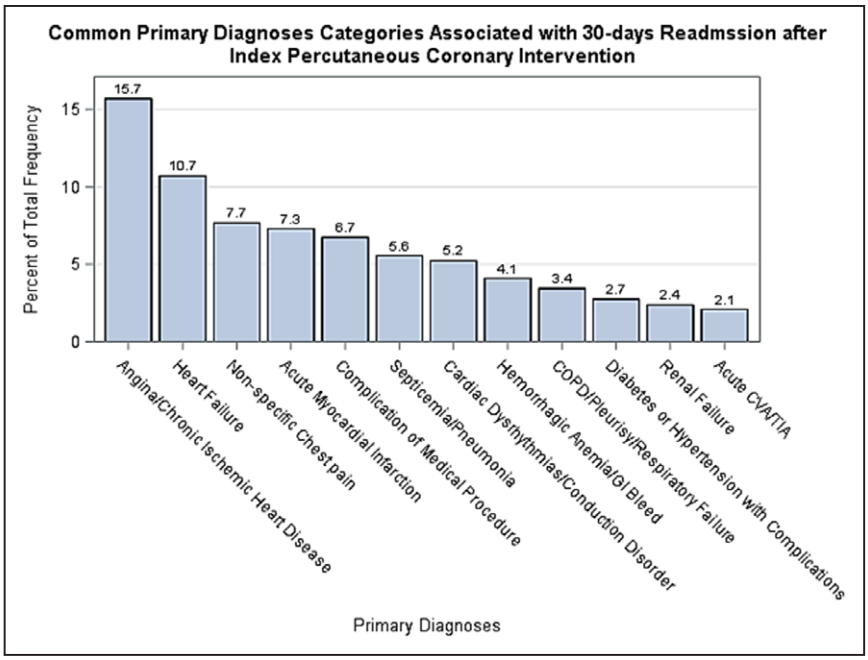

Figure 2. Common primary diagnoses associated with 30-day readmissions after percutaneous coronary interventions. COPD indicates chronic obstructive pulmonary disease; CVA, cerebro-vascular accident; GI, gastrointestinal; and TIA, transient ischemic attack.

disease, and chronic renal failure were associated with higher risk of 30-day readmission (all *P* values <0.01). In addition, longer index hospital stay and hospital-level factors, including payor source as Medicare/Medicaid compared with private insurance, hospital location in large metropolitan areas compared with smaller suburban/rural areas, hospitals with larger bed capacity, nonteaching hospital status compared with teaching hospital status, and nonelective admissions compared with elective admissions, were associated with higher risk of 30-day readmission (all *P* values <0.01). In the final parsimonious model, AMI at index admission, history of ischemic heart disease, percentile median household income by zip code of residence, and weekend versus weekday admission were not found to be significant predictors of 30-day readmission.

Table 2 presents univariate and multivariable hierarchical regression analyses to assess the association of readmission on $\log_{10}$-transformed cumulative costs over 30 days postindex PCI. The results showed that 30-day readmission increases the cumulative cost by 45% (β coefficient, 0.45; 95% confidence interval, 0.45–0.46; *P* value <0.001). Among other covariates, older age, female sex, AMI, higher Charlson Comorbidity Index, and chronic medical conditions including heart failure, peripheral artery disease, and chronic pulmonary disease were associated with higher cumulative costs (all *P* values <0.01). In addition, longer length of index hospital stays, higher percentile median household income, payor source as private insurance compared with Medicare/Medicaid, and nonelective admission were associated with higher cumulative costs (all *P* values <0.01). In our cohort, diabetes mellitus, chronic renal failure, hospital size and location, and teaching hospital status were not found to be significant predictors of cumulative costs.

We performed a sensitivity analysis to assess the differences in costs for index PCI hospitalization among patients who had 30-day readmission versus no readmission. Multivariable hierarchical regression analysis showed that mean costs of the index hospitalization were 3% higher among patients who had post-PCI 30-day readmission (β, 0.033; 95% confidence interval, 0.028–0.038; *P*<0.001). Among covariates, older age, male sex, private insurance compared with Medicare/Medicaid, higher Charlson Comorbidity Index, longer hospital stay, AMI at admission, and nonelective admission were associated with higher costs (all *P* values <0.01; Table III in the Data Supplement).

Discussion

To the best of our knowledge, this is the first study to examine the rate and costs of 30-day readmissions after index PCI using a national database of inpatients which includes 722 hospitals across the United States. Unlike prior studies that have examined readmission rates in select populations such as Medicare and statewide databases, and regional hospital systems, this study helps close the gap in the literature by examining patients across the spectrum of all age groups, insurance types, and across state lines. Our results on the association of readmissions with healthcare costs of PCI are important given that there is only 1 prior study which has examined costs of post-PCI readmissions in Veterans Affairs Hospitals.[18] Our results showed that ≈1 in 8 patients were readmitted within 30 days of discharge after index PCI. These readmissions were associated with a substantial increase of ≈45% in the mean short-term costs. The majority of the readmissions were for nonspecific chest pain or angina which did not require coronary revascularization. Furthermore, in a large sample of hospitals, our results highlight an almost 3-fold difference in readmission rates between the highest and lowest deciles.

In the Medicare population, the mean 30-day readmission rate in 2000 to 2012 was 16% with a relatively small decline in the rate over the years.[13] Similarly, data from the New York State PCI registry reported 16% all-cause 30-day readmission.[12] However, a lower rate of 30-day readmission of 11% was reported in the Veterans Affairs database.[18] Our results showed that in a large national database of inpatient PCI cases, the rate of 30-day readmission was lower than

Table 2. Univariate and Multivariable Regression Analysis to Assess the Association of Readmission Within 30 Days on Total Cost of Percutaneous Coronary Intervention

	Univariate Association			Final Multivariable Model*		
Variable	β	95% CI	*P* Value	β	95% CI	*P* Value
30-d Readmission (Ref: No)	0.573	0.566 to 0.579	<0.001	0.454	0.449 to 0.459	<0.001
Age ≥65 y (Ref: 18–64 y)	0.069	0.065 to 0.074	<0.001	0.013	0.007 to 0.019	<0.001
Female (Ref: Male)	0.031	0.026 to 0.035	<0.001	0.021	0.002 to 0.040	0.028
Acute MI	0.160	0.156 to 0.165	<0.001	0.062	0.058 to 0.066	<0.001
Charlson Comorbidity Index†	0.118	0.116 to 0.120	<0.001	0.016	0.013 to 0.019	<0.001
Comorbid condition (Ref: No)						
Ischemic heart disease	0.116	0.111 to 0.121	<0.001	n/a		
Heart failure	0.316	0.311 to 0.321	<0.001	0.072	0.067 to 0.077	<0.001
Peripheral artery disease	0.111	0.104 to 0.118	<0.001	0.015	0.009 to 0.021	<0.001
Chronic pulmonary disease	0.125	0.119 to 0.131	<0.001	0.008	0.003 to 0.013	0.001
Diabetes mellitus	0.046	0.041 to 0.051	<0.001	ns		
Renal failure	0.198	0.192 to 0.205	<0.001	ns		
Percentile median household income by Zip (Ref: 0–25th)						
26–50th	−0.011	−0.017 to −0.004	<0.001	0.002	−0.003 to 0.006	0.523
51–75th	−0.017	−0.024 to −0.010	<0.001	0.006	0.001 to 0.011	0.017
76–100th	−0.027	−0.035 to −0.019	<0.001	0.013	0.007 to 0.019	<0.001
Insurance (Ref: Private insurance)						
Medicare	0.091	0.086 to 0.957	<0.001	−0.005	−0.009 to 0.001	0.066
Medicaid	0.083	0.073 to 0.092	<0.001	−0.019	−0.027 to −0.013	<0.001
Other/self-pay/uninsured	−0.006	−015 to −0.004	0.234	−0.016	−0.022 to −0.008	<0.001
Hospital bed size (Ref: Small)				ns		
Large	−0.150	−0.235 to −0.066	<0.001			
Medium	−0.172	−0.250 to −0.093	0.001			
Large urban metropolitan (Ref: Small/Rural area)	0.080	0.032 to 0.129	0.001	ns		
Teaching hospital (Ref: No)	−0.083	−0686 to 0.0316	0.474	ns		
Length of index hospitalization, d	0.058	0.058 to 0.058	<0.001	0.052	0.054 to 0.052	<0.001
Elective Admission (Ref: No)	−0.177	−0.183 to −0.170	<0.001	−0.077	−0.082 to −0.071	<0.001

Model also adjusted for interaction term between age and female. CI indicates confidence interval; MI, myocardial infarction; n/a, not applicable to the hierarchical logistic regression analysis model; ns, not significant (not included in the final regression model); and Ref, reference.

*Represents final parsimonious hierarchical logistic regression model.

†Charlson Comorbidity Index is a composite score created from 17 comorbidities; higher scores have been correlated with greater morbidity and mortality.

previously reported; however, given the inherent differences in the risk profile of inpatient and outpatient PCI cases, our results should not be compared with other studies which have included both inpatient and outpatient PCI cases. In addition, there has been a decreasing trend in post-PCI readmission rates nationally over the past decade.[13] This downward trend in post-PCI readmissions may also be a possible explanation of the lower rates found in our study compared with prior.[6,12,13,15]

We found significant variability in readmission rates across hospitals, with some hospitals having mean readmission rates post-PCI of 6%, whereas other hospitals had a mean rate of 17%. Similar variability among hospitals has been reported previously in the Medicare data.[13,15] The reason for variability in the hospital readmission rate is most likely multifactorial. Several factors such as casemix, specific quality control measures, adoption of radial access to minimize vascular complications, individualized follow-up, and regional or geographical considerations in discharge planning may impact the readmission rate.[3,7,10,19] Future research should examine clinical, social, and policy-level factors underlying significant differences in post-PCI readmission rates among hospitals across the nation. Understanding these factors may be crucial in developing recommendations and protocols applicable to varied settings.[10,15,20] We found that older age, female sex, and higher comorbidities had an association with readmission risk and were associated with higher cumulative costs. In addition, multivariable analyses showed that Medicare/Medicaid-insured patients were 2 to 3× more likely

to have 30-day readmission compared with those who had private insurance, although minimal differences were found in cumulative costs between the 2 groups. These findings are consistent with HCUP report that although all-cause readmissions among patients covered by Medicare declined in 2011 to 2013, the overall rate of 30-day readmission was highest among patients covered by Medicare followed in decreasing order by those covered by Medicaid, the uninsured, and private insurance. Several unmeasured confounders such as patient-level perception of better coverage for services and hospital-level logistics may be responsible for the higher rate of short-term readmissions in Medicare patients compared with those on private insurance. However, the literature remains scarce on this topic, and further research is warranted to understand the differences in readmission rates by type of insurance.[21]

Literature on the association of short-term readmission after PCI on costs is lacking.[5] To the best of our knowledge, this study is the first to examine costs associated with readmissions in a national sample. The mean 30-day cumulative costs for those who were readmitted were $17 000 higher than those who did not have a readmission. The multivariable results showed that the readmissions accounted for a 45% increase in cumulative costs. Bradley et al[18] examined postindex PCI 30-day cumulative costs among 62 Veterans Affairs Hospitals from 2008 to 2011 and reported median costs comparable to our data at ≈$24 000. These data suggest a substantial financial impact of 30-day readmissions post-PCI; however, it is important to view these results in the context of whether or not these readmissions could be attributed to the index PCI. The literature suggests that a large proportion of 30-day readmissions after index hospitalization may be unrelated to the index diagnoses/procedure and could frequently be because of social or mental health reasons.[22,23] Identifying patients at a higher risk of readmission using the proposed prediction models may also facilitate necessary steps such as close outpatient follow-up and social work support to help mitigate the risk of unnecessary inpatient readmissions and thereby reduce the overall costs.[8,14]

Previous studies of selected populations have also reported that approximately half of the short-term readmissions post-PCI were because of noncardiac causes.[9,12,13,15,18,24,25] For example, in a recent study which examined a large healthcare system database for 2008 to 2012, ≈50% readmissions within 3 months after index AMI were found to be for non-AMI and noncardiovascular reasons.[25] We found that nonspecific chest pain/angina was the primary diagnosis for almost one fourth of readmissions, whereas AMI and procedural complications accounted for a relatively smaller fraction of readmissions. We found that the vast majority of readmissions did not require coronary revascularization. In our data, <4% patients who underwent revascularization during the readmission had associated diagnoses of AMI. Therefore, it could be inferred that a majority of the readmissions with nonspecific chest pain/angina did not require any intervention. Our data did not allow for identifying staged PCIs; however, ≈11% of readmitted patients had coronary revascularization done without a diagnosis of acute coronary syndrome and could potentially have been staged interventions. These data are comparable to a study by Wasfy et al[9] which examined PCI discharges from 2 hospitals in Massachusetts in 2014 and suggested that ≈7% of readmissions were for staged procedures. Nonetheless, our results reiterate that only a small fraction of 30-day readmissions were actually directly related to the index PCI. This is notable because there is growing implementation of bundled payments and the Medicare Access and CHIP Reauthorization Act of 2015 which penalize hospitals with higher risk-adjusted 30-day readmission rates regardless of the cause.[1,26,27] The full impact of bundled payments and Medicare Access and CHIP Reauthorization Act of 2015 is yet to be seen on post-PCI readmission rates. These policies may encourage hospitals to develop better strategies to prevent expensive short-term readmissions. However, the question still remains whether hospitals should be penalized for non-PCI–associated readmissions. In addition, the literature suggests that meeting quality metrics such as short-term readmission rates may not predict better outcomes.[28] Overall, our results support the need for further research to examine the preventability of 30-day readmissions after PCI and to explore whether or not short-term readmissions after PCI represent a good metric for hospital performance and health outcomes.

The results should be interpreted in the context of several limitations. In recent years, the proportion of outpatient PCI compared with inpatient PCI has been increasing. It is possible that compared with inpatients, the readmission rate may be lower in outpatients because they tend to be relatively lower risk patients. Our data did not include visits to emergency departments or admission to observation units after index PCI. In recent years, there has been an increasing trend of observing patients with nonspecific chest pain/angina in emergency departments or under observation status rather than inpatient admission.[21,29] Therefore, it is possible that we are not able to capture at least some of the readmissions which would lead to an underestimation of true rates. Regardless, it has been shown that the admission to observation units is cost-effective; however, the rates of such admissions remain low.[7] We have reported the rate of mortality during the 30-day readmission and do not have information about out-of-hospital mortality in patients discharged after PCI. Therefore, our mortality estimates could be lower than the actual 30-day post-PCI mortality. We were not able to define readmissions because of staged PCI. Nonetheless, similar to previous studies, inclusion of staged PCI as readmissions is important for estimation of total costs.[12,13] Information about race and ethnicity is not provided in the NRD. Previous studies have suggested that nonwhite race/ethnicity is associated with higher 30-day readmission rates after PCI.[10,15] We used ICD-9 codes for defining clinical conditions and procedures which may lead to misclassification bias. Nevertheless, a large body of literature validates the use of administrative databases and the results.[7,10–12,21,30] Finally, NRD includes discharge information from 21 states across the United States and represents a national population; however, our results cannot be considered completely generalizable.

Conclusions

Unlike prior studies which have used specific payor databases and local databases, this study examined post-PCI readmission rates and the association of readmissions on overall short-term

costs in a sample of inpatients PCI cases. Our results show that ≈1 in 8 patients is readmitted in a national database of inpatient PCI cases. There is significant variability in the rate of readmission among hospitals. Medicare patients compared with non-Medicare patients were at a higher risk of readmission. Patients who were readmitted incurred higher costs for index PCI compared with those who did not have 30-day readmission. In addition, readmissions substantially increased the short-term cumulative costs of PCI. A majority of readmissions were for low-risk chest pain/angina which did not require further intervention. This implies that the preventability may lie in attentiveness to general medical issues including counseling and increased access to outpatient care especially in the first few weeks after post-PCI discharge. However, there are several unmeasured confounders such as socioeconomic, mental, and geographical factors which may account for differences between the readmitted and nonreadmitted patients. The relationship between causes and readmission should therefore be interpreted in context of several probable unmeasured confounders. Our results warrant further research to better understand the causal association of short-term readmissions with index PCI and to examine the preventability of the readmissions. These efforts will facilitate policies and strategies to mitigate the rate of unnecessary readmissions and thereby help reduce overall cost burden.

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Drs Tripathi and Bhatt had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analyses.

Disclosures

Dr Bhatt discloses the following relationships: he is a member of advisory board in Cardax, Elsevier Practice Update Cardiology, Medscape Cardiology, Regado Biosciences; is a member of board of directors in Boston VA Research Institute, Society of Cardiovascular Patient Care; is member of chair in American Heart Association Quality Oversight Committee; is a member of data monitoring committees in Cleveland Clinic, Duke Clinical Research Institute, Harvard Clinical Research Institute, Mayo Clinic, Mount Sinai School of Medicine, and Population Health Research Institute; receives honoraria from American College of Cardiology (Senior Associate Editor, Clinical Trials and News, ACC.org), Belvoir Publications (Editor in Chief, Harvard Heart Letter), Duke Clinical Research Institute (clinical trial steering committees), Harvard Clinical Research Institute (clinical trial steering committee), HMP Communications (Editor in Chief, Journal of Invasive Cardiology), Journal of the American College of Cardiology (Guest Editor; Associate Editor), Population Health Research Institute (clinical trial steering committee), Slack Publications (Chief Medical Editor, Cardiology Today's Intervention), Society of Cardiovascular Patient Care (Secretary/Treasurer), WebMD (CME steering committees); and plays other roles in Clinical Cardiology (Deputy Editor), NCDR-ACTION Registry Steering Committee (Chair), VA CART Research and Publications Committee (Chair); receives research funding from Amarin, Amgen, AstraZeneca, Bristol-Myers Squibb, Chiesi, Eisai, Ethicon, Forest Laboratories, Ironwood, Ischemix, Lilly, Medtronic, Pfizer, Roche, Sanofi Aventis, The Medicines Company; receives royalties from Elsevier (Editor, Cardiovascular Intervention: A Companion to Braunwald's Heart Disease); acts as a site coinvestigator for Biotronik, Boston Scientific, St. Jude Medical (now Abbott); acts as a trustee of American College of Cardiology; and receives unfunded research from FlowCo, Merck, PLx Pharma, and Takeda. The other authors report no conflicts.

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Thirty-Day Readmission Rate and Costs After Percutaneous Coronary Intervention in the United States: A National Readmission Database Analysis

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Supplemental Material

Supplementary Table 1: Deyo's Modification of Charlson's Co-Morbidity Index (CCI).		
Reported ICD-9 CM Codes	**Condition**	**Charlson Score**
410 – 410.9	Myocardial Infarction	1
428 – 428.9	Congestive Heart Failure	1
433.9, 441 – 441.9, 785.4, V43.4	Peripheral Vascular Disease	1
430 – 438	Cerebrovascular Disease	1
290 – 290.9	Dementia	1
490 – 496, 500 – 505, 506.4	Chronic Pulmonary Disease	1
710.0, 710.1, 710.4, 714.0 – 714.2, 714.81, 725	Rheumatologic Disease	1
531 – 534.9	Peptic Ulcer Disease	1
571.2, 571.5, 571.6, 571.4 – 571.49	Mild Liver Disease	1

250 – 250.3, 250.7	Diabetes	1
250.4 – 250.6	Diabetes with Chronic Complications	2
344.1, 342 – 342.9	Hemiplegia or Paraplegia	2
582 – 582.9, 583 – 583.7, 585, 586, 588 – 588.9	Renal Disease	2
140-172.9, 174-195.8, 200-208.9	Any malignancy including leukemia and lymphoma	2
572.2 – 572.8	Moderate or Severe Liver Disease	3
196-199.1	Metastatic solid tumor	6
042 – 044.9	AIDS	6

Supplementary Table 2. Causes of 30-Day Readmissions Categorized According to Clinical Classifications Software (CCS) , Ninth Edition in the Primary Diagnosis Position		
Causes of Readmission	**CCS code(s)**	**ICD-9 Codes**
Septicemia or Pneumonia	2, 122, 129	0031 0202 0223 0362 0380 0381 03810 03811 03812 03819 0382 0383 03840 03841 03842 03843 03844 03849 0388 0389 0545 449 77181 7907 99591 99592 00322 0203 0204 0205 0212 0221 0310 0391 0521 0551 0730 0830 1124 1140 1144 1145 11505 11515 11595 1304 1363 4800 4801 4802 4803 4808 4809 481 4820 4821 4822 4823 48230 48231 48232 48239 4824 48240 48241 48242 48249 4828 48281 48282 48283 48284 48289 4829 483 4830 4831 4838 4841 4843 4845 4846 4847 4848 485 486 5130 5171 00322 0203 0204 0205 0212 0221 0310 0391 0521 0551 0730 0830 1124 1140 1144 1145 11505 11515 11595 1304 1363 4800 4801 4802 4803 4808 4809 481 4820 4821 4822 4823 48230 48231 48232 48239 4824 48240 48241 48242 48249 4828 48281 48282 48283 48284 48289 4829 483 4830 4831 4838 4841 4843 4845 4846 4847 4848 485 486 5130 5171 5070
Blood Loss Anemia or GI Bleed	59, 60, 153	2800 2801 2808 2809 2810 2811 2812 2813 2814 2818 2819 2820 2821 2822 2823 2824 28240 28243 28244 28245 28246 28247 28249 2827 2828 2829 2830 2831 28310 28311 28319 2832 2839 2840 28401 28409 2841 28411 28412 28419 2842 2848 28481 28489 2849 2850 28521 28522 28529 2858 2859 2851 4560 45620 5307 53082 53100 53101 53120 53121 53140 53141 53160 53161 53200 53201 53220 53221 53240 53241 53260 53261 53300 53301 53320 53321 53340 53341 53360 53361 53400 53401 53420 53421 53440 53441 53460 53461 5693 5780 5781 5789
Acute CVA or TIA	109, 112	34660 34661 34662 34663 430 431 4320 4321 4329 43301 43311 43321 43331 43381 43391 4340 43400 43401 4341 43410 43411 4349 43490 43491 436 4350 4351 4352 4353 4358 4359
COPD or Pleurisy or Respiratory Failure	127, 130, 131	490 4910 4911 4912 49120 49121 49122 4918 4919 4920 4928 494 4940 4941 496 5100 5109 5110 5111 5118 51189 5119 5120 5128 51281 51282 51283 51284 51289 5180 5181 5182 5173 5185 51851 51852 51853 51881 51882 51883 51884 7991 V461 V4611 V4612 V4613 V4614 V462
Renal Failure	157	5845 5846 5847 5848 5849 586
Complication of Medical Procedure or Implant/Graft	237, 238	27950 27951 27952 27953 41402 41403 41404 41405 41407 44030 44031 44032 56960 56961 56969 59682 59683 62931 62932 99600 99601 99602 99603 99604 99609 9961 9962 99630 99631 99632 99639 9964 99640 99641 99642 99643 99644 99645

		99646 99647 99649 99651 99652 99653 99654 99655 99656 99657 99659 9966 99660 99661 99662 99663 99664 99665 99666 99667 99668 99669 9967 99670 99671 99672 99673 99674 99675 99676 99677 99678 99679 99680 99681 99682 99683 99684 99685 99686 99687 99688 99689 99690 99691 99692 99693 99694 99695 99696 99699 99931 99932 99933 27950 27951 27952 27953 41402 41403 41404 41405 41407 44030 44031 44032 56960 56961 56969 59682 59683 62931 62932 99600 99601 99602 99603 99604 99609 9961 9962 99630 99631 99632 99639 9964 99640 99641 99642 99643 99644 99645 99646 99647 99649 99651 99652 99653 99654 99655 99656 99657 99659 9966 99660 99661 99662 99663 99664 99665 99666 99667 99668 99669 9967 99670 99671 99672 99673 99674 99675 99676 99677 99678 99679 99680 99681 99682 99683 99684 99685 99686 99687 99688 99689 99690 99691 99692 99693 99694 99695 99696 99699 99931 99932 99933 27661 27783 27788 2853 28741 3490 3491 34931 41511 4294 4582 45821 45829 5121 5122 5187 5190 51900 51901 51902 51909 53086 53087 53640 53641 53642 53649 53901 53909 53981 53989 5642 5643 5644 5696 56962 56971 56979 5793 59681 78062 78063 78066 9093 99524 9954 99586 9970 99700 99701 99702 99709 9971 9972 9973 99731 99732 99739 9974 99741 99749 9975 99760 99761 99762 99769 99771 99772 99779 9979 99791 99799 9980 99800 99801 99802 99809 9981 99811 99812 99813 9982 9983 99830 99831 99832 99833 9984 9985 99851 99859 9986 9987 9988 99881 99882 99883 99889 9989 9990 9991 9992 9993 99934 99939 9994 99941 99942 99949 9995 99951 99952 99959 9996 99960 99961 99962 99963 99969 9997 99970 99971 99972 99973 99974 99975 99976 99977 99978 99979 9998 99980 99981 99982 99983 99984 99985 99988 99989 9999 V1553 V1580 V1583 V9001 V9009
Diabetes or Hypertension With Complications	49, 50, 99	24900 25000 25001 7902 79021 79022 79029 7915 7916 V4585 V5391 V6546 24901 24910 24911 24920 24921 24930 24931 24940 24941 24950 24951 24960 24961 24970 24971 24980 24981 24990 24991 25002 25003 25010 25011 25012 25013 25020 25021 25022 25023 25030 25031 25032 25033 25040 25041 25042 25043 25050 25051 25052 25053 25060 25061 25062 25063 25070 25071 25072 25073 25080 25081 25082 25083 25090 25091 25092 250934010 40200 40201 40210 40211 40290 40291 4030 40300 40301 4031 40310 40311 4039 40390 40391 4040 40400 40401 40402 40403 4041 40410 40411 40412 40413 4049 40490 40491 40492 40493 40501 40509 40511 40519 40591 40599 4372

Cardiac Dysrhythmias/Conduction Disorder	105, 106	4260 42610 42611 42612 42613 4262 4263 4264 42650 42651 42652 42653 42654 4266 4267 42681 42682 42689 4269 V450 V4500 V4501 V4502 V4509 V533 V5331 V5332 V5339 4270 4271 4272 42731 42732 42760 42761 42769 42781 42789 4279 7850 7851
Heart Failure	108	39891 4280 4281 42820 42821 42822 42823 42830 42831 42832 42833 42840 42841 42842 42843 4289
Acute Myocardial Infarction	100	4100 41000 41001 41002 4101 41010 41011 41012 4102 41020 41021 41022 4103 41030 41031 41032 4104 41040 41041 41042 4105 41050 41051 41052 4106 41060 41061 41062 4107 41070 41071 41072 4108 41080 41081 41082 4109 41090 41091 41092
Non-Specific Chest Pain	102	78650 78651 78659
Angina and Chronic Ischemic Heart Disease	101	4110 4111 4118 41181 41189 412 4130 4131 4139 4140 41400 41401 41406 4142 4143 4144 4148 4149 V4581 V4582
Abbreviations: *GI: Gastrointestinal; COPD; Chronic Obstructive Pulmonary Disease: CVA: Cerebrovascular accident; TIA: Transient ischemic attack*		

Supplementary Table 3: Multivariable hierarchal regression models to assess the difference in index PCI hospitalization costs between those with 30-day readmission versus no readmission			
	Final Multivariable Model[**]		
Variable	**β**	**95% CI**	***P***
30-day Readmission (Ref: No)	0.033	0.028, 0.038	<0.001
Age ≥65 years (Ref: 18-64 years)	0.005	0.001, 0.010	<0.001
Female (Ref: Male)	-0.018	-0.067, -0.057	<0.001
Acute MI	0.095	0.090-0.101	<0.001
Charlson's comorbidity Index[#]	0.031	0.028-0.034	<0.001
Comorbid Condition (Ref: No)			
Ischemic heart disease	-0.045	-0.051, -0.039	<0.001
Heart failure	0.058	0.053, 0.063	<0.001
Peripheral artery disease	ns		
Chronic pulmonary disease	-0.007	-0.012, -0.002	0.006
Diabetes mellitus	-0.016	-0.020, -0.011	<0.001
Renal failure	-0.019	-0.025, -0.013	<0.001
Percentile median household income by Zip (Ref: 0-25th)			
26-50th	-0.011	-0.017, -0.005	<0.001
51-75th	-0.012	-0.017, -0.006	<0.001
76-100th	-0.007	-0.012, -0.001	0.012

Insurance (Ref: Private insurance)			
Medicare	-0.004	-0.008,0.001	0.102
Medicaid	-0.017	-0.024, -0.014	<0.001
Other/self-pay/uninsured	-0.007	-0.011, -0.001	<0.001
Hospital bed size (Ref: Small)	ns		
Large			
Medium			
Large urban metropolitan (Ref: Small/Rural area)	ns		
Teaching Hospital (Ref: No)	ns		
Length of Index Hospitalization (days)	0.058	0.053, 0.054	<0.001
Elective Admission (Ref: No)	-0.062	-067, -0.057	< 0.001